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Model-Test Optimization of an OWC Wave Power Plant

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ABSTRACT

The present paper describes experimental studies in an irregular wave tank concerning a 1/35 scale model of a bottom-standing wave power plant of the oscillating-water-column (OWC) type, to be built spanning a small natural harbour in the island of Pico (Azores). The purposes of the experiments were to determine the power plant's most suitable location, geometry and dimensions, as well as to allow the overall characteristics of the mechanical and electrical equipment to be optimized, and to provide the experimental data required to estimate the annual production of energy.

INTRODUCTION

The oscillating water column (OWC) is probably the most extensively studied type of wave energy device and one of the very few to have been deployed at full-scale in the sea. The best-known other type to have reached the demonstration stage is the tapered channel device or TAPCHAN, of which a prototype has been operating in Norway since 1985. Two of the OWC prototypes built so far are bottom-standing caissons and are located in the harbour of Sakata, Japan (Goda et al., 1989; Moto et al., 1991) and in a fishing harbour near Trivandrum, India (Raju et al., 1991). The rated power and water depth are 60 kW and 20 m for the first device, and 125 kW and 12 m for the second one. They combine the functions of wave power devices and breakwater elements, with the advantage of the constructional costs being shared between the breakwater and the power plant. Two other OWC prototypes were built directly on rocky coastline. One of them, with a rated power output of 500 kW, was operational at Toftestallen, Norway, between 1985 and 1988. See report of the Norwegian Ministry of Petroleum and Energy, 1987. Its concrete-walled air chamber was built in an excavation made on the cliff. The other, a smaller prototype of 75 kW, was installed more recently in a natural gully in the isle of Islay, Scotland (Whittaker et al., 1991), with the natural walls of the gully forming the bottom and parts of the side walls of the chamber. A self-rectifying air-turbine of the Wells type was adopted as the power takeoff machine in every case.

Plans to build a wave power plant in the Azores archipelago started in 1986, following several years of research and development work on wave energy at Universidade Técnica de Lisboa and at Laboratório Nacional de Engenharia e Tecnologia Industrial, Portuguese Ministry of Industry and Energy. The chosen site is located in the deeply indented shoreline of Porto Cachorro, in the volcanic island of Pico (population about 15,000), at 38°33'N, 28°29'W, 1700 km west of the Portuguese mainland. The structure of the OWC power plant is planned to be a caisson standing on the bottom in 7-m-deep water between the rocky walls of a small natural harbour where natural concentration of wave energy has been observed. The device will be equipped with a Wells turbine driving an asynchronous electrical generator. This paper describes the tests, performed in an irregular-wave tank, on a 1/35 scale model in order to optimize the precise location, geometry and dimensions of the device structure, and also to determine the specifications for the mechanical and electrical equipment and to estimate the annual electrical energy output.

SITE DESCRIPTION AND WAVE CLIMATE

Porto Cachorro, extending along a few hundred metres on the northern coastline of Pico (one of the nine Azores islands), was the site chosen for the power plant mainly because it combines a favourable coastline morphology with a good exposure to the most energetic wave direction. The average tidal amplitude is 0.8 m, ranging from 0.3 m to 1.3 m. The local coastline is made of basalt resulting from 18th century volcanic activity, and is very irregularly indented, forming several small harbours with nearly vertical walls, rocky bottom and water depths of the order of 6 to 10 m. Fig. 1 shows its most interesting part.

Wave data for the model test experiments were obtained by combining information on wave climate from three different sources: (i) Data (1983-88) from the U.K. Meteorological Office wind-wave hindcast/forecast numerical model for that area of the Atlantic, complemented since 1987 by data of the same kind and for the same area from Instituto Nacional de Meteorologia e Geofísica, Lisbon; (ii) measurements by a nondirectional Waverider buoy deployed in 100-m-deep water about 2 km off Porto Cachorro for a period of 17 months (1988-89); (iii) measurements with ultrasonic probes suspended above the water at several points considered favourable for siting a power plant (Pontes and Justino, 1990 a, b). Measurements (ii) and (iii) were recorded for 3-h periods of 20 min. Although the northern coast of Pico is partly sheltered by the neighbouring islands of Faial and São Jorge, the angle of exposure at Porto Cachorro is relatively wide (about 90 degrees) and its bisector is approximately in the most energetic direction of the waves (330°N) as given by numerical wind-wave modelling for that area of the North Atlantic.

Several places within the area represented in Fig. 1 were initially considered for an OWC structure, and indeed local wave measurements with ultrasonic probes and model testing were done for three of them. In-situ construction of the air chamber spanning gully *F* represented in Fig. 1, a technique adopted in the isle of Islay, was an attractive option from the structural point of view.

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